TOWARDS ULTRA-HIGH RESOLUTION CLIMATE SIMULATION USING A TWO-WAY NESTED MODEL: PRECIPITATION AND EXTREME EVENTS

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HIGH-RESOLUTION MODELING: LIMITED-AREA VS GLOBAL MODELS

• Boundary conditions of limited-area models become a problem for simulations longer than a few days
  • Require BCs supplied from a possibly-inconsistent global model, can cause boundary errors
  • No feedback onto large-scale

• Global models have no boundaries and provide a consistent solution everywhere, but global high resolution can be impractical
  • Solution: grid refinement of a global model!
THE GFDL FV$^3$ CORE

- Finite-volume D-grid model solving the vector-invariant (vorticity-KE form) hydrostatic primitive equations
  - Variables are cell- (or face-) averages, not point values
  - Flux-form scheme, so mass conserving
  - Vertically-Lagrangian hybrid-pressure coordinate
- Cubed-sphere grid in more recent versions
  - Non-hydrostatic version in late development
A message from our sponsor

- Nonhydrostatic core
- 2 km: c256 stretched by 20 (global model!!)
- Solo core with warm-rain microphysics

http://www.gfdl.noaa.gov/visualizations-mesoscale-dynamics
NESTING METHODOLOGY

- BCs: All variables linearly interpolated in space into nested grid halo
- Concurrent nesting: extrapolation in time so nest and coarse grids can run simultaneously
- Two-way update:
  - Averaging-update for temperature
  - Vorticity-conserving for winds
- **No** update for air and tracer mass: ensures mass conservation!!
WHY CLIMATE SIMULATION?  
(ONE POINT OF VIEW)

- Initial condition less important
- Running a climate simulation tests every resolved phenomenon repeatedly
- Errors have nowhere to hide!
  - But cause and effect of errors hard to diagnose—literally can be (thousands of) miles apart

Link between the double-Intertropical Convergence Zone problem and cloud biases over the Southern Ocean

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HURRICANE INTENSITY

North Atlantic

- IBTrACS
- 110 km
- 50 km
- 110 & 40 km
- 50 & 25 km

Nested-grid max intensity
JJA PRECIPITATION

PRISM Observations

$c_{90}$ (110 km) single-grid

$c_{192}$ (50 km) single-grid

$c_{360}$ (30 km) single-grid

$c_{90n3}$ (40 km) nest

$c_{192n2}$ (25 km) nest

mm/d
C384 SINGLE-GRID RESULTS

PRISM Observations

c360 (30 km) single-grid

c384 (25 km) single-grid

c384 Alternative configuration
New nest: c384n3

- c384 global grid (25 km)
- Factor-of-three nest (8 km) over CONUS
- 8 mo/day with 4248 cores (c384 single-grid: 19 mo/day with 3456 cores)
C384 AND C384n3

PRISM Observations

C360 (30 km) single-grid

C384 (25 km) single-grid

C384 Alternative configuration

C384n3 (8 km) nested
Central United States

JJA Precip (mm/hr)

- GCIP
- c90 1g
- c192 1g

Local Time

One day
Central United States

- GCIP
- c192 1g
- c90 1g
- c192 n2

JJA Precip (mm/hr)

Local Time

One day
One day
One day
Parameterized Precipitation

Resolved Precipitation
GCIP Observations

c90 (110 km) single-grid

c384 (25 km) single-grid

c384n3 (8 km) nested

One day
CONCLUSIONS

• Enhanced resolution readily improves representation of orographic precipitation and hurricane intensity

• Great Plains precipitation only improves weakly with increasing resolution

• Nesting to 8 km gets the best results, especially in representing propagating features in the Northern Plains

• Want to avoid parameterization as much as possible to get the diurnal cycle right!!